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Review Article

Genetic variability and heritability in Ethiopian mustard (Brassica carinata A.Braun)

Takele Mitiku Abdeta*

Department of Plant Science, Ethiopian Institute of Agricultural Research, Ambo University, Ethiopia

Correspondence email: takelemitku202@gmail.com

Abstract

Ethiopian mustard (*Brassica carinata* A. braun 2n=34), is a species that is one of the six most economically important species on the planet. It originated in north-eastern Africa, most likely on the Ethiopian plateau, as a natural hybrid between *Brassica nigra* and *Brassica oleracea*. Even though, the crop has high economic importance, production is limited by a scarcity of high-yielding early mature types, a high concentration of erucic acid (C22: 1) in seed oil, and a high glucosinolate content in the meal. Mustard is mostly farmed in Ethiopia's Central and Southeastern Plateaus' mid- to high-altitude (1700-2800 m asl) areas, which receive 500-1200 mm of annual rainfall. The oldest amphidiploid is B. napus, which is followed by *B. juncea* and *B. carinata*. Ethiopian mustard is an annual, biennial, or perennial crop used in Ethiopia for oilseeds or as a green vegetable. Brassicas are economically important species by supplying vitamins, minerals, trace elements, dietary fiber, protein and oil for human consumption and industrial raw materials, as well as feed and condiments. Interspecific hybridization has increased the Brassica crops gene pool by transferring beneficial features from one species to another. High heritability and high genetic progress suggested additive effects, whereas high heritability and low genetic advance indicated dominance and epistatic effects. In Ethiopian mustard, different variables like the heritability of days to flowering, days to maturity, plant height, and 1000 seed weight is high.

Keywords: Ethiopian mustard, Heritability, Genetic advance, Variability.

INTRODUCTION

Ethiopian mustard (*Brassica carinata*) is an important oil crop that has been grown in Ethiopia as an oilseed and vegetable crop since antiquity. Higher altitudes (2000-2600m) and more fertile, well-drained soil, which is frequently close to the homestead, are ideal for the crop. One of the six economically important species is *Brassica carinata*, popularly known as Ethiopian mustard. It evolved naturally as a hybrid between *Brassica nigra* and *Brassica oleracea* in north-eastern Africa, most likely on the Ethiopian plateau, where wild forms of *B. nigra* have co-existed with cultivated forms of *B. oleracea* since antiquity (Tsunoda, 1980).

Ethiopian mustard, also known as "Gomenzer" in Amharic, is traditionally used to grease bread baking clay pan used for baking the traditional Ethiopian cuisine "enjera," as well as to treat illnesses and stomach upsets and produce special beverages. Arsi, Bale, Gonder, Gojam, Wello, Shewa Sidamo, and Wellega are the most important mustard-growing regions in Ethiopia, with 550,000-750,000 quintals produced in areas ranging from 30,000 to 45,000 hectares in the last five years (CSA 2011/12 - 2015/16). Ethiopian mustard plants' leaves are abundant in vitamin C and K, beta carotene, and cancer-fighting antioxidants, while also being mild in bitterness. Vegetable relish can be found in the leaves of immature plants (Nigussie & Becker. 1990). Furthermore, it is used as a break crop in farming systems to produce cereals with similar ecological amplitude, particularly in large-scale farms (Oleszek, 1987).

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Ethiopian mustard ranks third in overall production and area among highland oilseeds in Ethiopia, after niger seed and linseed (CSA, 2013/2014). At the level of private peasant holdings, its expected area and output are 44041.34 hectares and 62450.266 tons, with an average productivity of 1.418 tons/ha (CSA, 2013/14). Ethiopian mustard thrives in locations with cool, lengthy growing seasons and high rainfall, such as those between 2200 and 2800 meters above sea level. During the growth season, temperatures and rainfall in these places range from 12 to 18°C, while rainfall ranges from 500 to 1200 mm (i.e., June to December). It flourishes in both heavy sandy loam and light clay soils with proper drainage (Getinet et al., 1994).

The Ethiopian mustard's main production limits, according to (EARO, 2000), are a scarcity of high-yielding early mature types, a high concentration of erucic acid (C22: 1) in seed oil, and a high glucosinolate content in the meal. Improvements in seed oil and meal quality to meet Canola quality standards, as well as the development of early maturing cultivars with high yields, are key concerns in Ethiopian mustard breeding programs (Getinet et al., 1994).

Despite the lack of solid statistical data on mustard distribution and production in Ethiopia, with modest yields, the crop has been widely grown in various sections of the country (Tesfaye et al., 2011). This could be because mustard has received little attention from research and development initiatives (Jianchu et al., 2001), and its genetic resources are depleting due to physical and physicochemical factors (Mulualem & Ayenew, 2012). As a result, in recent decades, the country has experienced substantial genetic degeneration. Genetic variety is recognized to be the most important raw resource in every breeding operation (Zemede, 1992; Genet et al., 2005). Determining the level of variety and identifying variants within the gathered species is critical for genetic improvement and crop conservation (Mulualem & Weldemichael, 2013).

Evolutionary forces of (mutations, selections, migrations, and random genetic drift) with the impact of man through selection and domestication results in genetic diversity in crop plants (Allard, 1988). Within a taxon, genetic variation is not evenly distributed across the geographic area where it is spreading (Frankel et al., 1995), and populations from afar are expected to accumulate greater genetic diversity than populations in close proximity (Chandel & Joshi, 1983). Detecting and quantifying the degree of dissimilarity among species, subspecies, populations, and elite breeding materials is crucial in plant breeding and population genetics (Rief et al., 2005). As a result, the purpose of this review is to assess Ethiopian mustard genetic variability, heritability, and genetic advancement (*Brassica carinata* A. Braun).

LITERATURE REVIEW

Origin, domestication and cultivation of mustard

Ethiopian mustard (2n=34) is supposed to have come from the highlands of Ethiopia's plateau, as well as other portions of East Africa and the Mediterranean coast. It was created through chromosomal doubling from a natural cross between B. nigra (BB) (n=8) and B. oleracea (CC) (n=9) (Nagaharu, 1935). It has the genomic constitution BBCC and is largely amphidiploid. Ethiopian mustard ranks third in overall production and area among highland oilseeds in Ethiopia, after niger seed and linseed (CSA, 2013/2014). Ethiopian mustard thrives in locations with a cool, those between 2200 and 2800 meters above sea level, for example, have a long growth season and a lot of rain. It grows well in either a sandy loam or a light clay soil with good drainage (Getinet et al., 1994).

Brassica carinata (n = 17) was created by crossing Brassica oleracea (n = 9) with Brassica nigra (n = 8). *Brassica carinata*, often known as Ethiopian mustard, evolved naturally in the horn of Africa from a hybrid between *Brassica nigra* and *Brassica oleracea* (Nigussie & Becker. 1990). The mustard oil concentration of *B. nigra* and the slow steady development of *B. oleracea* distinguish this species. There are no wild varieties of *B. carinata*, but rudimentary domesticated species are farmed in Ethiopia's highlands and further south into Kenya. This hybrid could have developed as a result of kale land races of *B. oleracea* crossing with wild or semi-domesticated *B. nigra* varieties. Kale and carinata thrive in the chilly climates found on the Ethiopian plateau. They are grown in kale gardens by local farmers. This name, which has been translated into a variety of languages and dialects, is widely used in country side where vegetables originating from *B. oleracea* kinds are grown. Carinata crops are also known as guomin, Abyssinian mustard, or Ethiopian cabbage, and supply leafy vegetables as well as oil sources. Cabbage is a generic name for a variety of cole brassicas that isn't often connected with the elegant heads found on store aisles today. Within the three amphidiploid species, there is a lot of genetic variability (Song et al., 1996). According to genetic variability research, *B. napus* is the most ancient amphidiploid, followed by *B. juncea* and *B. carinata*.

Mustard is mostly farmed in Ethiopia's Central and Southeastern Plateaus' mid- to high-altitude (1700-2800 m asl) areas, which receive 500-1200 mm of annual rainfall. *B. carinata* evolved as a natural hybrid between *B. nigra* (BB n=8) and *B. oleracea* (CC n=9) in Ethiopia's highlands and the surrounding area of East Africa and the Mediterranean coast, followed by chromosome doubling, where both parental species were sympatric (Nagaharu 1935; Mizushima 1980;

Shigesaburo-Tsunoda 1980; Hemingway 1995). Although the species has no wild forms (Shigesaburo-Tsunoda, 1980), there are a number of eco-types with distinct morphological and agronomic traits (Abebe et al., 1992). It outperforms *B. napus* in Ethiopia when it comes to yield, disease resistance, and seed breaking. *B. carinata* can be a valuable source of genes that are uncommon in other oilseed brassicas, as well as having a higher resistance to semiarid conditions (Knowles et al., 1981; Fereres et al., 1983; Malik 1990). The diversity and eco-geographic pattern of variability should be explored in order to make advantage of such key genes (Bhatt, 1970; Jain and Singh, 1972; Jain et al., 1975; Kjellqvist, 1975; Jain 1977; Arunachalam, 1981).

Despite the absence of comprehensive statistical data on mustard distribution and production in Ethiopia, the crop is widely planted with low yields in many sections of the country (Tesfaye et al., 2011). This could be because mustard has received little attention from research and development initiatives (Jianchu et al., 2001), and its genetic resources are depleting due to physical and physicochemical factors (Tewodros & Biruk, 2012).

Morphology description of Ethiopian mustard

Ethiopian mustard is an annual, biennial, or perennial crop used in Ethiopia for oilseeds or as a green vegetable. Epigeal germination allows the cotyledons to sprout above earth, allowing them to be photosynthetically active and counteracting the negative consequences of a lack of reserve food within the seed. The taproot of B. carinata is long and prolonged, with many laterals that can reach a length of one meter or more. With multiple branches and a short petiole, the stem and leaves are both green and dark green.

The inflorescence of B. carinata is a long raceme that grows at the end of the main stem and branches. The flowers are bright yellow in color, however they can also be orange or creamish white. The fruit is a silique (pl = siliqua), a long, slender pod made composed of two carpels separated by a false septum. The seeds are largely embryonic and small, and the prevailing hues are brown and yellow (Setia, 1980).

Economic importance of Ethiopian mustard

Brassicas are commercially important species that provide human-use oil, industrial raw materials, fodder, and sauces. They are used as fodder and sauces and are grown as leaf & root vegetables (Getinet et al., 1994). Ethiopian mustard is a valuable source of oil and a green vegetable in Ethiopia's mid-altitude and highland regions (1700 to 2800 meters a.s.l). The seed is used for oil extraction, greasing traditional bread baking clay pans (Mitad), treating specific diseases, and preparing beverages at an early stage of development, while the leaf is used as a vegetable, either by thinning or topping (Alemayehu, 2001). After oil extraction, the protein-rich meal can be utilized as a high-protein feed supplement (as long as the glucosinolate content is reduced) or as organic fertilizer (Nigussie & Becker. 1990). In industry, it is used in the tanning of leather, the production of varnishes, the production of diesel fuel, soap, and lighting (Downey, 1971; Bhan, 1979).

Ethiopian mustard is a healthy vegetable that may be used in a variety of dishes. Vitamins, minerals, trace elements, dietary fiber, and protein are all present. It also lends a little of zest and spice to dishes (Zemede, 1992; Genet et al., 2005).

Genetic variability in Ethiopian mustard (Brassica carinata A. Brun)

Genetic diversity arises during evolution as a result of the combination of evolutionary forces (mutations, selection, and random genetic drift) with the influence of man through domestication and selection (Allard, 1988). Genetic diversity, which represents the frequency of different types in a group, is used to measure individual variety (Frankel et al., 1995). It aids in the analysis of cultivar genetic variability, the selection of parental materials for hybridization in order to create new gene recombination, the selection of inbred parents or testers in order to maximize heterotic response, and the identification of materials that should be preserved in order to preserve maximum genetic diversity in germplasm sources.

Populations from far away are predicted to accrue more genetic variety than populations in close proximity (Chandel and Joshi, 1983). The level of genetic variety between parents determines the genetic improvement achieved through hybridization and selection. The D2 statistic is one of the most important biometrical methods for evaluating genetic divergence in a population. The D2 is a genetic divergence metric between genotypes, both within and between clusters. Crosses between genotypes from clusters separated by the greatest generalized distance and exhibiting the most divergence are logical.

By transferring favorable traits from one species to another, interspecific hybridization has enlarged the gene pool of Brassica crops (Allard, 1960; Prakash and Chopra 1998). An interspecific cross between *B. carinata* and *B. rapa* (AA, 2n =20) produced a hexaploid hybrid (AABBCC) that was proven to be suitable as a bridge hybrid. By combining the hexaploid hybrid with *B. napus*, a pentaploid hybrid was created (AABCC). The DNA from this pentaploid hybrid was then used to create a *B. napus* variant with half of the *B. rapa.* A genome and half of the *B. carinata* C genome (Li et al., 2006). Several interspecific crosses involving B. carinata have been conducted, with some of B. carinata's favorable traits being passed to other Brassica species (Choudhary et al., 2000, Rahman 2001; Tonguc and Griffiths, 2004).

Morphological and agronomic features differed across *B. carinata* accessions. Young stems and leaves had different colors, especially in major leaf vein. Some plants were purple in color, making them stand out against the greenery. The accessions' bolting and blooming periods ranged from 90 to 212 days. Abebe et al. (1992) found that genotypes of *B. carinata* obtained from different locations of Ethiopia have a wide range of morphological and agronomic features. Furthermore, Alemayehu (2001) investigated 36 genotypes of Ethiopian mustard for agronomically relevant features and discovered a large level of genetic variability.

Different phenotypic features of Ethiopian mustard were described by (Teklehaymanot et al., 2019), leaf apex, leaf color, petiole length, chlorophyll content, principal branch, plant height, and leaf area are all factors to consider. The most common leaf shape was elliptic, although there were also obovate orbicular, ovate, and a variety of shapes. The color of Ethiopian mustard accessions are light green, green, purple green, and deep green. Acute, moderate, rounded, and a variety of leaf apex types were found.

Different traits in Ethiopian mustard, such as date of flowering, maturity, seed yield per plot, oil content, oil yield, number of seed per plant, thousand seed weight, number of primary branches, number of secondary branches, plant height, palmitic, stearic, oleic, linoleic, linolenic, and erucic acid, show a lot of variation, according to the (Nigussie & Becker. 1990; Adefris, 2005) both found differences in fatty acid contents across Ethiopian mustard germplasm accessions.

Heritability in Ethiopian mustard (Brassica carinata A. Brun)

Genetic progress, which expresses the direct link between heredity and response to selection, is a measure of genetic gain under selection (Shukla et al., 2004). For efficient selection, it is vital to understand heritability and genetic advancement (as a percentage of the mean) (Khan et al., 1992; Sarawgi et al., 1997; Choudhary et al., 1999; Pant & Singh, 2001; Mahmood et al., 2003; Akbar et al., 2003). The most effective condition in breeding programs is thought to have high genetic progress combined with high heritability estimates for a certain trait.

Selecting the best people and successfully developing mustard genetics requires a combination of high heritability and strong genetic advancement. High heritability combined with high GAM for secondary branches per plant, number of pods per plant, harvest index, and oil output per plot indicates the presence of additive gene effects for these characteristics. Only the number of seeds per pod, the number of pods per plant, and the length of pod had high GAM values, whereas the number of seeds per pod, the number of pods per plant, and the length of pod all had low GAM values. High heritability in combination with high genetic advance indicated additive gene effects (Khulbe et al., 2000; Ghosh & Gulati, 2001; Akbar et al., 2003; Aytaç & Kinaci, 2009), whereas high heritability in combination with low genetic advance indicated dominance and epistatic effects (Khulbe et al., 2000; Ghosh & Gulati, 2001; Akbar et al (Alemayehu & Becker, 2002).

Selection is more effective in improvement endeavors when heritability is combined with genetic progress (Sheikh et al., 1999; Ghosh & Gulati 2001; Singh et al., 2003). High genetic progress and heritability are crucial selection strategies. Heritability provides information on how qualities are passed down from parents to offspring, which aids in selection (Aytac Z. & colleagues, 2009). Plant breeders can utilize heritability evaluation to forecast genetic development below assortment, allowing them to be optimistic about success from various types and intensities of selection.

Calculates genetic progress for biomass yield per plot based on the number of first branches and seeds per plot. Plant height showed the greatest genetic progress and had the highest heritability, whereas grain filling period and days to maturity showed a similar trend in heritability and genetic advance.

According to Yared S, days to flowering, plant height, 1000-seed weight, and days to maturity exhibit high heritability (2016). Delesa (2006) discovered that variables such days to flowering, days to maturity, plant height, and 1000 seed weight have a high heritability in Ethiopian mustard. Days to blooming, plant height, and 1000-seed weight have all been found to be highly heritable in other brassica species (Robbelen and this, 1980; major and Singh 1996; Becker et al., 1999; De et al., 2000; Ali et al., 2003; Aytac & Kinaki, 2009).

CONCLUSION AND RECOMMENDATION

In Ethiopia, there is enough evidence of the existence of several genotypes of Ethiopian mustard to optimize the conservation and utilization of mustard genetic resources, which could have major implications for growers' and consumers' diverse needs in light of future climatic, edaphic, and biotic challenges. Ethiopian mustard has a low grain yield despite its genetic diversity and favorable agro-ecological conditions for production. This is due to a lack of knowledge about the crop, which makes it difficult to improve its genetic make-up through different breeding techniques, as well as a lack of breeding facilities and the use of classical breeding/conventional breeding methods in Ethiopia, which limit Ethiopian mustard's production potential. The crop is used for both fresh consumption and oil production. Because Ethiopia has such a complex agro-ecology, intercrossing distant mustard varieties can lead to genetic advancement. As a result, selection can easily occur in a variety of genetic variations.

Rather than employing conventional/classical breeding, Ethiopian mustard should be supported by current agricultural research technology such as biotechnology, marker assisted selection of characteristics, molecular markers, genomic mapping, and alternative culture techniques. Farmers and breeders should be well-versed on the importance of crops. It is better if the crop is for oil to create cash income rather than for fresh cooking consumption to make the crop more essential.

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